УДК 539.21

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EFFECT OF SURFACE STATES ON ELECTRON FIELD EMISSION FROM SEMICONDUCTORS

In the process of developing new technologies of solid-state and vacuum electronics, a particular problem is the creation of new efficient semiconductor emitters. The final theory of the laws of the emission current of semiconductors has not yet been developed.

In experimental studies for semiconductors, both elementary and binary, with an atomically clean surface, it has been shown that the field emission current is generated by electrons from the valence band, and in some cases surface states located in the band gap and valence bands of the semiconductor take part in the emission [1-3].

In [1], the energy distribution of electrons from a field emitter made of an n-GaAs single crystal coated with a thin layer of its own oxide was experimentally studied. Further, the energy distribution of electrons from the (111) plane of a germanium single crystal during field emission and the dependence of the energy spectra on the external field strength were experimentally studied. The main peak corresponds to energies below the bottom of the valence band E_c.

Traditional field emission calculations neglected to the semiconductor surface potential profile in the presence of an external field. In this case, no attention is paid to the presence of a narrow potential well formed by the polarization potential near the surface

$$V_p(x)=\left(\frac{\varepsilon-1}{\varepsilon+1}\right)\frac{e^2}{4x}, \tag{1}$$

where ε is the dielectric constant of material, and e is the elementary positive charge. Eq. (1) is exactly the image charge potential at the plane surface of a dielectric.

In this work, the one-dimensional Schrödinger equation for the ABDFG potential at the Figure (the case of no field) for germanium and gallium arsenide is solved. The image potential (1) is cut off at a distance x_0 (in the Bohr radii a_0)

from the surface. Then the electron momentum component is quantized along the normal to the surface ($x-$axis), and parallel to the surface ($yz-$plane), the spectrum of values of the momentum components is continuous. Figure shows an energy diagram that corresponds well to zero temperature, when a semiconductor turns into a dielectric.

The presence of a surface subband (SS) was discovered, the bottom E_{ss} of which lies bellow the valence band one E_v (see Table). At a non-zero temperature, as well as the presence of an electric field and band bending, the ACDFJ-potential profile will be even more favorable for the formation of the deeper band. Thus, the presence of a surface band below the Fermi level and E_v qualitatively explains the shift in the energy spectrum of emitted electrons discovered in [1, 2].

Table – Imput data and calculated the surface subband bottom E_{ss}.

Material	E_c, eV	E_v, eV	ε	x_0, a_0	E_{ss}, eV
Ge	-4,00	-4,75	16,0	0,15	-6,59
GaAs	-4,07	-5,50	12,5	0,15	-6,37

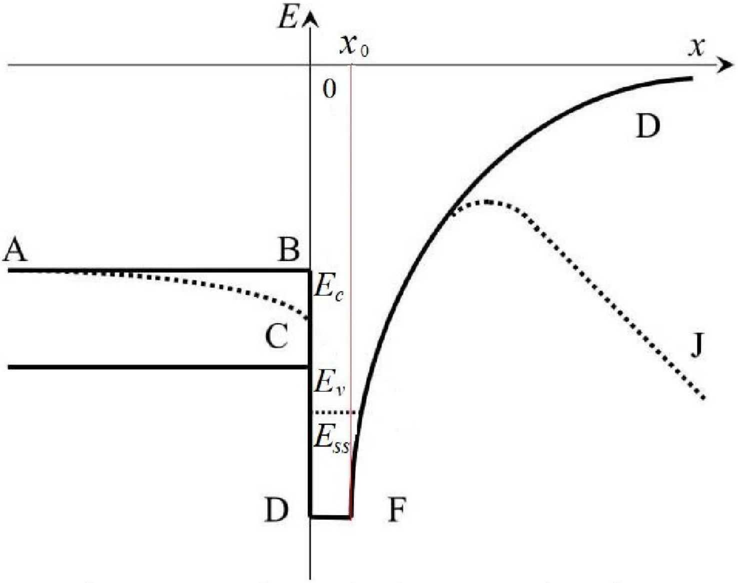

Figure – Energy diagram for electrons near the surface

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